University of Cambridge
School of Agriculture Memoirs

Memoir No. 21

A summary of the papers published by the members of the Staff of the School of Agriculture and its Associated Research Organisations during the period Oct. 1st, 1948—Sept. 30th, 1949.

Review Series

No. 4. Animal Nutrition Research at Cambridge — A Retrospect.

CAMBRIDGE
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FOREWORD

This Memoir, which is published under the general editorship of the Librarian of the School, represents an attempt to present as succinctly as possible the contributions made by members of the Staffs of the School of Agriculture and its Associated Research Organisations to the development and progress of Agricultural Science, to indicate to research workers interested the Journals in which the full papers are presented and to act as a complete record of papers published. Each summary is compiled by the author of the paper and is presented, so far as the subject matter will allow, in a non-technical form in order to be of value to the general body of farmers interested in the more recent developments of agricultural scientific research in general and of the activities of this Department in particular.

Requests for further information or criticism arising out of the summaries should be referred to the individual author concerned, criticisms and suggestions for the improvement of the Memoir itself should be addressed to the Librarian of the School.

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THE SCHOOL OF AGRICULTURE, 1899—1949

On the afternoon of 13 July, 1949 there foregathered in the Hall of St. John's College many past and present members of the teaching, office and laboratory staffs of the School of Agriculture. The occasion was informal and domestic, to celebrate the 50th year of the School's formal existence and commemorate its founders, and to honour, on his retirement, a very loyal and devoted servant of the School, Mr. W. H. Nobbs, who, during his 45 years of service had endeared himself to all with whom he came into contact.

It was but natural and fitting that Professor Sir Frank Engledow in the course of his address should mark the occasion by referring to the origin, growth and development of the School, and in this article an attempt has been made to recapture for more permanent record than the minds of his listeners can provide, the salient points of his address and to touch on some other aspects of the School's history.

The story of the School falls into four natural periods, a pre-history period of six years during which the teaching of agriculture was fighting for University recognition ; a foundational period extending from the formal recognition by the University in 1899 of the School as a University Department to the outbreak of war in 1914, a growth period from 1918 to 1939 during which the teaching, research and advisory activities of the School were developing their full scope ; and a maturation period from 1945—1949 during which many of the research and advisory activities were given a separate corporate existence, with the School once more resuming its pristine simplicity as a Department of the University with that simple linkage of teaching and research which is in the academic tradition.

Informal teaching of agriculture at the University began as the result of the over optimism of a Chancellor of the Exchequer, who, anticipating the passing of a Licensing Bill decided to create a compensation fund by the inclusion of an increased duty on spirits in his budget in 1889. The Bill however was rejected by Parliament and the Chancellor was left with an unexpected surplus which was handed over to the newly created County Councils to be used for Technical Instruction. Foreseeing the demand for agricultural teachers as the result of many of the Councils deciding to use this money for furthering agricultural education, the President of the Board of Agriculture (the late Viscount Chaplin) suggested to the Chancellor of the University in a letter dated 25 July, 1890 the founding of a Department of Agriculture, and a syndicate was appointed to consider the suggestion and report on its possibilities. After two years discussion the syndicate presented its report recommending the creation of a Department of Agriculture, and not for the first time in its history, the University rejected a syndicate's recommendation on the plea of lack of funds. Meanwhile active steps had been taken to commence informal teaching at Cambridge, and in the Long Vacation of 1891 Professor Liveing (of St. John's and then Professor of Chemistry in the University), a member of the Syndicate, organised a class for senior students who proposed to take up agricultural teaching. Among those who took the course it is interesting to note the names of John Percival, R. H. Adie, Cecil Warburton and T. B. Wood. At the same time Professor Liveing and Professor McKenny Hughes had begun negotiations with representatives of neighbouring County Councils, as the result of which the Cambridge and Counties Agricultural Education Committee came into being. This Committee aided by an initial grant from the Cambridgeshire County Council and annual grants from this and neighbouring Counties and the Board of Agriculture began in January 1893 to give an organised course of instruction in agricultural science. Headquarters were in rooms lent by Professor Liveing in the basement of the Chemical Laboratory, and the Committee maintained a room in St. Mary's passage as a reading room and library. Meanwhile in November 1893 the second report of the syndicate recommending the institution of a Diploma in Agriculture was accepted by the University and the first examination for the Diploma took place in July, 1894. In January, 1894, T. B. Wood returned to Cambridge to act as Secretary of the Committee, to teach agricultural chemistry, and to supervise manurial experiment stations established by the contributing County Councils. During this stage of development the Committee frequently found itself in financial straits owing to lack of funds, indeed in 1897 the question of closing the venture had been seriously discussed but in 1898 largely through the instrumentality of the Cambridge County Council and the organising ability of its Secretary of Education, the late Austin Keen, the finances of the Committee were placed on a more secure footing. Development was then fairly rapid. In 1896 the University had received its first benefaction for agriculture in the form of an endowment for 21 years of a lecturership in the History and Economics of Agriculture by the late Sir Walter Gilbey. This was reinforced by the offer of a second benefaction from Sir Walter in 1898 of a capital sum sufficient to maintain a lecturership for a period of 10 years and in the same year the Worshipful Company of Drapers offered to endow for 10 years a Professorship of Agriculture on condition that the University founded and maintained a Department of Agriculture and recognised agriculture or agricultural science as a subject of study for a degree.

These bequests, reinforced by the promise of an increased annual grant from the Board of Agriculture at last satisfied the University that a new Department could be maintained on a satisfactory financial basis, and in the early months of 1899 the University formally took over the work of the Cambridge and Counties Committee as a going concern. The diploma examinations were remodelled and the first examination was recognised as a special examination for the ordinary B.A. degree.

The newly constituted Department of Agriculture began work in October 1899 with Somerville as the first elected Drapers Professor, with T. B. Wood as Lecturer in Agricultural Chemistry and R. H. Biffen as Lecturer in Agricultural Botany. The accommodation consisted of four small rooms in the basement of the University Chemical Laboratory and a small room in the Botany School lent by Professor Marshall Ward. In the year after its establishment the School got its first farm—Burgoyne's Farm of 140 acres near the church at Impington. It was generously leased, rent free, for 10 years by the late Mr. Macfarlane-Grieve and set up with a working capital of £1,500 collected by public subscription. In 1902 Professor Somerville, who during his short stay had done much towards establishing the new School as a Scientific Department of the University,

resigned to join the Board of Agriculture and was succeeded by T. H. Middleton. During Middleton's tenure of the Professorship a link with overseas agriculture was established, a number of students readily obtaining good positions in India and the Colonial Territories, Professor Middleton's Indian experience being important in encouraging this development. Middleton left Cambridge in 1907 to become, like his predecessor, Assistant Secretary at the Board of Agriculture and T. B. Wood was elected to the Chair.

By this time the Department had outgrown its temporary accommodation and the need for permanent and more spacious premises was urgent. Through the active interest of the Duke of Devonshire, who was Chancellor of the University, an appeal for £20,000 to build an agricultural laboratory was launched and aided by the Worshipful Company of Drapers, who opened the subscription list with a donation of £5,000, the required sum was soon forthcoming. Although the Duke of Devonshire did not live to see the scheme he initiated come to fruition, his son, who had succeeded him as Chairman of the Appeal Committee, took an active interest in the scheme, and on the 26 April, 1910 formally opened the School of Agriculture. Coincidentally with the occupation of the new building and the termination of the lease of the Impington Farm, the University was enabled to obtain through the good offices of Trinity College the lease of Gravel Hill Farm, consisting of about 200 acres of land conveniently situated between the Huntingdon and Madingley roads and not more than 1½ miles from the School buildings. Under Wood and Biffen, aided by K. J. J. Mackenzie who had charge of the agricultural teaching and management of the University Farm, and Dr. F. H. A. Marshall who initiated and developed the teaching of Agricultural Physiology, the School made its influence felt not only on agricultural teaching, but also on agricultural research. So much so that in 1912 the Animal Nutrition Institute and the Plant Breeding Institute were established under the direction of Professors Wood and Biffen respectively, and staffed by research workers aided for the most part by scholarships awarded by the Board of Agriculture. Provision was also made for advice and guidance to farmers by the setting up of an Advisory Service. Hardly had the Research and Advisory Services got into their stride when the Great War intervened and for nearly five years the buildings were occupied by army troops and war agricultural committees, with the skeleton staffs of the School left in possession occupying their thoughts and activities with problems of wartime food production. With the return of peace in 1918, the elevation of the Board of Agriculture to a Ministry in 1919, and the influx of considerable funds made available by the repeal of the Corn Production Act of 1921, the teaching, research and advisory services of the Department made rapid headway. Teaching grew into a degree course in 1921, and soon embraced Horticulture and Estate Management. Horticulture as a teaching subject started bravely under C. W. B. Wright but after a few years terminated owing to lack of students, though its research activities continued as a Research Institute under the direction of D. Boyes. Estate Management however under the successive direction of F. B. Smith, E. P. Weller and N. Dean grew from strength to strength until in 1946 it was reconstituted as a separate Department of the University and now caters for Urban Estate Management as well as Rural. During the middle period between the two wars teaching for those already graduated in pure sciences and intending to specialise in some aspect of agricultural science became a notable development. Into this came the training of men destined for the Agricultural Services in the Colonial territories and through whom the influence of the School was extended to Cyprus, Aden and Malaya, to Hong Kong round to the West Indies, over both sides of Africa, far south to Fiji and into little known places like Zanzibar and the Seychelles Islands. As in the early period the training of specialists for India and the Colonies grew out of the specialised knowledge Middleton possessed of these countries, so in the latter period Engledow's contact with tropical agricultural systems both in the Middle East during the 1914—18 war and afterwards in the Colonies and Dependencies as a member of numerous Government Commissions has been the motivating force in the development and success of this post-graduate teaching. With the development of the Research Institutes grew the need for recording in permanent form the result of those researches, their translation into terms capable of adoption in farming practice and the testing and multiplication of new crop plants to a commercial stage. Thus there resulted the publication of the Journal of Agricultural Science, the first of all British scientific agricultural publications, unique in the simplicity of its publishing organisation, and honoured throughout the world. The success of the Advisory services, particularly in the practical benefit derived by farmers in the rationing of farm livestock and in the control of plant pests and diseases, has led not only to an appreciation by farmers of the benefits of agricultural research but also to an industrial demand for advice on such a scale that it has become necessary to set up a great National Advisory Service. The testing of new varieties of crop plants and their multiplication to a stage suitable for marketing grew beyond the normal resources of a Research Institute, and this task was undertaken by the National Institute of Agricultural Botany set up partly for this purpose and partly to carry out the testing of agricultural seeds.

In 1928 the Commonwealth Agricultural Bureau of Plant Genetics was set up in the School and the Commonwealth Potato Collection in 1940. Besides adding scientific strength, these mark the School's increasing connection with agriculture beyond our own shores. Through the strong growth of Agricultural Economics—a development unforeseen in the foundation period and with which the late Sir Daniel Hall is intimately associated—the School has been doubly enriched. In research it has been stimulative ; in teaching it has notably assisted in the advance of agricultural education from the technical, to the scientific and liberal.

The success of the Agricultural Research Institutes has marked out for them a magnitude requiring, in the judgment of authority, a physical capacity and administrative responsibility exceeding what can be provided in a University. They are therefore in the process of detaching themselves from the School and taking on independence in new homes of their own. As inheritors of the experimental tradition of our founders, we regretfully accept the decision to make this great experiment in the country's organisation of its science, and in wishing them well on their departure acknowledge with gratitude the contribution the Institutes have made to the growth and development of the School including its teaching.

What remains to the last needs fewest words ; it is of our founders. Their names are few but great. The first Drapers Professor was William Somerville (1899—1902), renowned for classical work on pastures ; T. H. Middleton (1902—1907) came next : throughout the distinguished official career which began when he relinquished the Professorship he remained the wise counsellor and staunch friend of the School. Thereafter came the 22 years' tenure of T. B. Wood to whose character and work the School owes more than can ever be expressed in words : indeed words are made unnecessary by the great number of living memories in which he is cherished. With these three, inseparably, we must recall their famous colleagues ; R. H. Biffen, world renowned for his work on cereals ; F. H. A. Marshall whose classical work on the physiology of reproduction will ever be remembered ; K. J. J. MacKenzie the first Director of the Farm ; Cecil Warburton, one of the British fathers of agricultural entomology, and R. H. Adie the School's first secretary.

These were the School's founders ; their merits are recorded in their scientific discoveries, in the careers of their pupils, and in the heritage now in our hands.

ANIMAL NUTRITION RESEARCH AT CAMBRIDGE—A RETROSPECT*

By

E. T. HALNAN, M.A.

(*University Lecturer in Agricultural Physiology and Zoology*)

Research in Animal Nutrition began with and found its full development under T. B. Wood. Born in 1869 at Habberley, Shropshire, Wood was educated at the High School, Newcastle-under-Lyme, and proceeding to Gonville and Caius College, Cambridge, with a Scholarship in Natural Science, took his degree in Natural Sciences with First Class Honours in June, 1891. After a comparatively short period as teacher of Agricultural Science, first as University Extension Lecturer in Devonshire, and then as Agricultural Science Master at the Norfolk County School, Wood came back to Cambridge in a dual capacity as Secretary to the Cambridge and Counties Agricultural Education Scheme and Lecturer in Agricultural Chemistry. As part of his duties Wood was responsible for the supervision and recording of field experiments carried out on various farms in the co-operating counties, and although these experiments were concerned mainly with farm crops, they included a series of bullock feeding experiments (Anon, 1898, 1899, 1902) carried out under the auspices of the Norfolk Chamber of Agriculture. The first experiment having settled to the satisfaction of the Committee that the old established Norfolk practice of feeding 1 cwt. of roots per head per day to fattening bullocks was a sound one (mainly be it noted on the butcher's report) a series of trials were initiated to test the relative economy of various rations of purchased foods as adjuncts to home grown roots and mixed chaff. Financially the bullock feeding experiments showed consistent losses, and an attempt to compare the feeding value of swedes grown under varying manurial treatments having proved inconclusive, Wood decided that an investigation into the variation in chemical composition of roots was a necessary preliminary to any further feeding trials, and, assisted by R. A. Berry he analysed a series of varieties of mangolds for dry matter, sugar and nitrogen content (Wood & Berry, 1905). These chemical investigations were followed up by bullock and sheep feeding trials in which Long Red mangolds were compared with Yellow Globes. The Long Red mangolds were proved to be superior to Yellow Globes for fattening full grown cattle, but equal to or slightly inferior to Yellow Globes for yearling cattle or store stock. This difference in behaviour was associated in the first case with the higher dry matter content of the Long Red variety and in the latter with its inferior nitrogen content (Anon, 1907). Meanwhile events of considerable importance to the future development of agricultural science had taken place. Emil Fischer's work on the chemistry of proteins and carbohydrates and Hopkins discovery of the essential nature of vitamins in animal nutrition had provided research workers with new weapons for attack on problems of the nutrition of farm animals, and the appearance of Goodwins' translation of Kellner's book " Grundzüge der Fütterungslehre " had concentrated the attention of those interested upon the possibility of placing the feeding of farm animals on a scientific basis, as well as upon the value of animal calorimeters as instruments for the study of the nutrition of farm animals. Hall had further published a paper on the variation of the composition of the swede turnip in which he had stressed the value of certain mathematical methods of analysis for ascertaining a measure of the reliability of results obtained in field trials (Hall, 1905).

As facilities for research increased Wood turned his attention to several lines of enquiry. Foremost in his mind was the need for placing animal feeding trials on a more exact basis, and by applying the ' probable error ' method to the data of a series of bullock trials showed that the relative values for fattening of two varieties of mangolds, Long Red and Yellow Globe, were in accordance with their respective dry matter contents (Wood, 1910). This paper was followed by another by Wood and Stratton (1910) in which the use of statistical methods for analysing the results of feeding trials was shown. The probable error of one animal in a feeding trial was found to approximate to 14% of the live weight increase, from which it was calculated that 29 animals in a lot were required to measure with reliability a difference of 10% between the live weight increases of two lots of animals. In a later experiment with pigs, Robinson and Halnan (1912) showed the probable error of one animal in a feeding trial to be 10% of the live-weight increase, the normal variation in

**This is the fourth of a series of articles summarizing phases of agricultural research particularly associated with the School of Agriculture since its inception. Further contributions on other work will appear in future issues.*

the live weight increase of pigs being less than that of bullocks, and a table was published giving the number of pigs required in a lot to ensure that a given difference in an experiment is not due to normal variation. Wood and Yule (1914), applying statistical methods to the records of English feeding trials, further demonstrated that in the fattening of animals under English conditions the law of diminishing returns came into play, the percentage utilisation of the production portion of a ration diminishing with the lengthening period of fattening, and the effect of this law on the application of Kellner's starch equivalent theory to fattening experiments was clearly demonstrated. The action of Wood and Yule in distinguishing between starch equivalent for maintenance and starch equivalent for production, as well as the accuracy of data used was later criticised by Murray (1915), a criticism that was later rebutted by Halnan (1915) who pointed out that the beauty of the Kellner system lay in the fact that it gave the comparative values and not the absolute values of various feeding stuffs for the fattening of farm animals. The importance of this early work of Wood resides in the fact that it concentrated attention on the use of statistical methods of analysis as a tool in the design and interpretation of field experiments and rendered possible the extraction of reliable conclusions from the results of field trials.

At the same time as Wood was studying problems of animal nutrition Biffen was busy evolving new varieties of cereals on Mendelian lines, paying particular attention to the inheritance of disease resistance and the production of a ' strong ' wheat suitable for growth under English climatic conditions. It was but natural that Wood should collaborate with Biffen by investigating the nature of ' strength ' in wheat flour. ' Strength ' in wheat flour was regarded as its capacity to produce when baked a ' large, well piled up loaf '. Largeness of loaf Wood found to depend on the capacity of the flour to give off gas when fermented with yeast, and shapeliness to be associated with the physical properties of the gluten as modified by varying proportions of salts. These properties which varied with concentrations of acid and salt were coherence, elasticity and water content (Wood, 1907). Later, Woodman (1922) isolated and compared the gliadin and glutenine proteins from ' weak ' and ' strong ' flours, and using the optical behaviour of these proteins when racemised by dilute alkali, came to the conclusion that, whereas the gliadin fractions were identical, the glutenine fractions differed in their chemical structure. Woodman postulated that the factor which determines the *size* of the loaf was the diastatic capacity of the flour as indicated by Wood, and the factor which determines the *shape* of the loaf appeared to be associated with the physical properties of the gluten and was possibly dependent on the particular glutenine mechanism possessed by the wheat. During the development of the wheat grain from the flowering stage to ripening Woodman and Engledow (1924) determined the order of appearance of the wheat proteins to be, sodium chloride soluble proteins (albumin, globulin and proteose), gliadin and glutenine. Halton (1925), following up Woodman's work on the glutenines found ' strength ' to be associated with a glutenine of high specific rotation and ' weakness ' with a glutenine of low specific rotation.

The study of the chemistry of proteins was given early prominence by Wood, in general owing to the fact that protein was a food nutrient of considerable importance, and in particular, owing to the fact that protein foods were dear foods and were used in large amount for fattening stock, a practical legacy from the early days of agricultural chemistry when it was firmly believed that fat was largely derived from protein. This protein study was entrusted to Foreman, whose analytical skill and original powers of thought made him well fitted to undertake a problem which eventually proved to be of considerable complexity. Foreman, utilising the then known methods isolated and estimated the amino-acid content of linseed protein, but found that these methods resulted in relatively poor yields, only approximately half of the total nitrogen of the protein being accounted for (Foreman, 1910). Dissatisfaction with these results led him to attack the problem of protein hydrolysis in general with a view to improving the methods commonly in use for the separation of the products of protein hydrolysis. In 1912 Foreman gave a preliminary account of an improved method of esterification, the process consisting of the formation of dry lead or copper salts of the amino-acids, formation of ester hydrochlorides and their removal by dry chloroform, conversion of the ester hydrochlorides into the esters by means of baryta, removal of the chloroform by controlled evaporation and separation of the mono-amino esters from the diamino substances by extraction with dry ether (Foreman, 1912). Hydrolysis of caseinogen by the new method gave increased yields of amino-acids (Foreman, 1919) and in 1913 the presence of amino-lactic acid and an unknown acid, half of whose nitrogen was in the amino form, was reported (Foreman, 1913). A year later Foreman reported a method for the quantitative estimation of aspartic and glutaminic acids, based on the insolubility of their calcium salts in alcohol and glacial acetic acid, and gave evidence to prove that 1-pyrrolidonecarboxylic acid present in aqueous solution of glutaminic acid was a derivation of glutamic acid (Foreman, 1914 a and b). Using Foreman's method Williams (1916) ascertained the amino-acid composition of the soluble protein of the swede turnip.

With the outbreak of the war more attention was given to war problems, and with Graham Smith, Foreman undertook an investigation into the prevention of nuisances arising from flies and putrefaction. The control of the fly nuisance was shown to be effective only if the eggs and larvae are destroyed in the breeding places, and larvicides of an oily nature were found to be most effective, in particular a mixture consisting of a coal tar creosote oil of country make to which sufficient bases extracted from " light oil " were added to make the proportion of bases to phenolic bodies approximately 1 to 2 was found to be most effective in the prevention of flies and putrefaction when sprayed on the carcasses of man and animals (Foreman & Graham-Smith, 1917). During these studies Foreman was impressed with the need for methods whereby chemical changes occurring in biological fluids during putrefaction by bacteria or other agents could be readily followed and he set out to evolve such methods. In 1920 Foreman published a paper giving rapid volumetric methods for the estimation of amino-acids, organic acids and organic bases in biological fluids (Foreman, 1920), and in 1928 in conjunction with Graham-Smith the value of these methods for investigating the changes produced in meat extract media by bacteria was demonstrated (Foreman & Graham-Smith, 1928). This was followed by a paper giving a

rapid method for removing the carbonic acid radical from cultures without exposing other constituents to risk of loss or change (Foreman, 1928a) and another in which a method for the rapid accurate estimation of ammonia or ammonium and volatile bases in fluids of biological interest was given (Foreman, 1928b). By this time a very active interest in pasture plants was being taken by research workers, and Foreman undertook a long and comprehensive study of the protein complexes present in the cytoplasm of pasture plants, using pure cultures of perennial rye grass and wild white clover at varying stages of growth. By applying the Chibnall ether method and various modifications of that method Foreman extracted and analysed the cytoplasmic protein complexes. From his studies Foreman provisionally concluded :—that the proteins in the cytoplasm of the leaf cells of perennial ryegrass occur as " protein complexes " in which the proteins are chemically associated with water soluble and water insoluble phosphorous substances. Two forms of complexes are postulated, protein ' complex a ' in which the protein is loosely combined with water soluble phosphorous substances, probably phosphates of sodium and potassium, and protein ' complexes b ' associations " rigid towards " water, including nucleo proteins and probably magnesium and calcium phosphate-protein. Protein ' complex a ' is regarded as acting as a reserve store to be drawn upon as required for the needs of the developing parts of the plant tissues such as growing points etc. and the fluctuating content of this complex brought about by stages in growth and environmental conditions such as weather and manuring is regarded as a matter of considerable nutritional importance. The content of ' complex a ' is regarded as determining the yield of " soluble protein " by the Chibnall extraction methods, ' complex a ' readily dissociating into its components under this treatment. The amount of protein extracted from the leaf tissues will therefore depend on the ratio of ' complex a ' and ' complex b ' in the tissues, high yields being obtained in cases where the ratio of ' complex a ' to ' complex b ' is high, and the high yield obtained from spinach leaves can be explained by the fact that the oxalic acid content of spinach leaves precluded the presence of high amounts of ' complex b ' in the cytoplasm of this plant.

Another major line of research initiated by Wood was the development of calorimeters suitable for the study of energy exchanges in farm animals. Prior to the 1914—1918 war, considerable progress had been made in the construction of a calorimeter by Wood and A. V. Hill, doubtless stimulated by the observation that the skin temperatures as ascertained by a suitably designed ' thermopile ' of " good doers " giving a daily live weight increase of over 2 lb. were invariably lower than those of " bad doers ", in which the daily live weight gain was much less (Wood & Hill, 1914). After the war J. W. Capstick completed the construction of the calorimeter and commented on its performance, pointing out that owing to its high heat capacity, the calorimeter was only suitable for long period experiments. (Capstick, 1921). With the assistance of T. Deighton and J. S. Morgan basal metabolism studies on swine were undertaken and considerable progress made. The resting metabolism of the pig during inanition was found to fall off in accordance with a curve which was the same over a wide range of weight and age of pig and temperature of surroundings, and the possibility of deducing the basal metabolism of a given pig from a single observation from a composite curve was indicated (Capstick & Wood, 1922a). The pig used by Capstick and Wood was well grown at the commencement of the work and a year later Deighton published observations on the basal metabolism of the young growing pig, starting with a pedigree large white at 59 days of age and measuring its basal metabolism at various periods of growth extending over a year. Deighton found the basal metabolism to vary during growth, the basal metabolism per unit area of surface during the mid-growth period being greater than at any other time of life. He also found that the energy metabolism after ingestion of a meal reached its maximum at 5 hours and then declined (Deighton, 1923). Capstick and Wood (1922b) further studied the effect of external temperature on the basal metabolism of the pig and found the critical temperature for swine to be 21°C., the basal metabolism at this temperature being 904 calories per square metre of surface per day, increasing by approximately 4% for every degree centigrade fall from this temperature. For very young animals Deighton found Capstick's calorimeter too large for the level of accuracy desired and he accordingly constructed an improved model on a smaller scale for use with young animals (Deighton, 1926). Meanwhile Wood combining the results of Deighton's metabolic studies on pigs with analyses of carcase composition of pigs at various ages, constructed the data from which it became possible to calculate the daily food requirements of pigs for any given level of liveweight increase (Wood, 1926). Deighton (1929), continuing his studies with the new calorimeter, measured the basal metabolism of the Middle White and the Berkshire pig at varying ages and established breed differences in basal metabolism, the fasting metabolism of the Middle White being definitely lower than that of the Large White studied earlier. Later, becoming dissatisfied by the magnitude of the error involved in calculating the surface area of animals by weight formulae ($\pm 20\%$) Deighton evolved a method, partly photographic and partly mathematical in which an accuracy of about $\pm 3\%$ could be attained (Deighton, 1932).

As indicated earlier, the calorimeter was only suitable for long period experiments and as soon as the need for short period experiments arose Deighton turned his attention to the construction of a new type of calorimeter on the ' compensatory ' or ' balanced ' principle as developed by Noyons, a small calorimeter suitable for use with fowls being first constructed with a view to building larger calorimeters later for work with pigs and other farm animals (Deighton, 1939). During its construction Deighton published in a series of three papers the main results of his studies on the fasting metabolism of the pig, two of the more important conclusions being that the metabolism in fasting is more a function of a power of the weight of the pig than of the surface area and net energy is a statistical rather than a physiological constant (Deighton, 1934, 1935, 1937). The new differential calorimeter in operation came fully up to expectation as a precision instrument excellently adapted to the measurement of a rapidly varying heat output, and two papers were published on the diurnal rhythm of heat production in fasting Light Sussex cockerels, the energy quota for standing and squatting, and the net energy of Sussex ground oats and white maize meal for fattening cockerels (Deighton & Hutchinson, 1940a and b). Meanwhile war had intervened and calorimetry studies had to be abandoned as having no direct bearing on the war effort, and with the retirement of Deighton later in the war period the calorimetry department ceased to function.

In attempting to apply the results of laboratory studies to farming practice, Wood had been faced with the problem of measuring the energy expended by the animal in the muscular activity exercised in the search for food, and preliminary experiments to measure this activity in the case of sheep by means of pedometers having failed, Wood sought for other methods of ascertaining the maintenance and production requirements of sheep under normal feeding conditions. By applying the method of least squares to the data obtained by Woodman in sheep digestibility trials, Wood and Capstick (1926) estimated the energy maintenance requirements of the adult sheep to be 1.1 lb. starch equivalent per square metre of surface per day, approximately 25% above that for basal metabolism. The production requirement of fattening sheep was then sought for by three methods (1) statistical treatment of feeding trial records (2) examination of data of specially designed feeding trials, and (3) comparative slaughter methods. From a study in which these methods were used, Wood came to the conclusion that the best round figure for the production requirement of fattening sheep is 2½lb. starch equivalent per lb. of liveweight increase (Wood, 1927). From these experiments Wood later showed that it was possible to ascertain the starch equivalent of foods which comprised the main part of a ration from controlled field trials using the formula $R=M+GK$ where R=average ration per head per week in lb. starch equivalent, M=average maintenance requirement in lb. starch equivalent, G=average liveweight increase per head per week in lb. and K=weight in lb. of starch equivalent required to make 1 lb. of liveweight increase. Using this formula in sheep feeding trials, Wood showed that on a dry matter basis the results for swedes agreed with those obtained by Kellner (Wood, 1927b), and Stewart in a later communication obtained similar agreement by application of this formula to Kellner's figures in the case of linseed cake (Stewart, 1928).

Wood in his approach to the problem of the scientific feeding of livestock gave great prominence to research on the nutritive values of feeding stuffs and by the time war broke out in 1914 digestibility cages and harness suitable for use with sheep had been constructed and tested by Halnan. With the outbreak of war, Wood's attention was directed towards the larger problem of maintaining food supplies for the human population. With Hopkins he published in 1915 a pamphlet in which the need for economy by the Nation in the consumption of food was emphasised, and guidance given in the construction of adequate diets for the different classes of the community (Wood & Hopkins, 1915). By 1917, owing to the indiscriminate sinking of shipping the food supply of the Nation was in a critical condition and Wood published a considered estimate of the National Food Supply and outlined the main principles that should operate if the best use of available supplies both for man and beast were to be made (Wood, 1917). The policy outlined in this booklet was to a large extent adopted some 22 years later when Great Britain once more found herself subjected to siege conditions.

With the resumption of peace in 1918 the Animal Nutrition Institute at Leeds was closed and the workers dispersed. This event gave added strength to the Cambridge Institute since it brought Woodman to Cambridge and marked the first beginning of a systematic study on the nutritive values of feeding stuffs and on the chemical changes undergone by farming crops during various methods of conservation. Woodman had already undertaken digestibility studies at Leeds with Crowther (Crowther & Woodman, 1917a and b), and, after a joint paper with Wood on the digestibility of oat and tare silage (Wood & Woodman, 1921) published in conjunction with Amos and others a series of papers dealing with silage. During the ensilage of a crop Woodman showed that the chief chemical changes occurring were breakdown of protein and cellulose and the development of non-volatile and volatile organic acids (Amos & Woodman, 1922), and the formation of phaeophytin, a magnesium-free derivative of chlorophyll. He further showed that two main types of silage could be produced, a " green fruity " silage and an " acid brown " silage, and indicated the conditions for producing these two types of silage (Woodman, 1923a). Later he found that the cellulose of the immature woody fibre of immature plants was more readily broken down than the lignified woody fibre of the mature plant (Woodman & Amos, 1924a). Other crop plants for silage production were studied. Both sunflowers and sugar-beet tops were found to be unsatisfactory for ensilage (Amos & Woodman, 1923 ; Woodman & Amos, 1926a) but maize proved very satisfactory and suitable varieties for ensilage were indicated (Woodman & Amos, 1924b, 1928). In addition to a study of the chemical changes taking place in a tower silo (Woodman & Amos, 1926b) Woodman published studies on the process of making clamp silage (Amos & Woodman, 1925) and stack silage (Woodman & Hanley, 1926 ; Woodman, 1925d). The process of making clamp silage was found to lead to excessive loss of food nutrients, and the stack silage process resulted in the spoilage of approximately 29% of the total stack and also a depression in the digestibility of the crude protein, this latter being associated with the transformation by bacterial action of part of the protein into a dark humin-like material. The usual analytical methods used in silage analysis proved faulty when applied to the ' sour ' silage produced by the stack method and a modified method suitable for general application was suggested (Woodman, 1925e).

In 1925 Woodman's interest switched from silage to grass and with his colleagues he undertook a comprehensive study of the nutritive value of pasture grasses as affected by various conditions of environment and management including manuring. The silage investigations had already influenced farming practice, the grassland investigations revolutionised pasture management and gave the farming community a new appreciation of the nutritive value and feeding possibilities of this much appreciated but somewhat neglected crop. Within the scope of this article it is not possible to deal with the work in detail and an outline of the main findings of this research must suffice. These are :—(1) close grazing of pasture affects the botanical composition of the pasture, but irrespective of the botanical composition, close grazed pasture yields dry matter high in protein which under close grazing is maintained throughout the season ; (2) dry matter of pasture herbage grown under a system of fortnightly cuttings is a protein concentrate equal to that obtained by a system of weekly cuttings, and under unfavourable meteorological conditions productivity is higher under a system of fortnightly cuttings; (3) young leafy pasturage can be dried at steam temperature or by direct heat in a kiln without affecting its digestibility and such material can be conserved and utilised as a protein concentrate substitute for oil cakes

in the winter ; (4) pasture obtained under a system of 3-weekly cuts though slightly less rich in protein is nevertheless equal in respect of total digestible organic matter and starch equivalent to grass grown under systems of weekly and fortnightly cuttings.

The new conception that young pasturage was in effect a watery protein concentrate and that dried young grass could compete with oil cakes as a protein concentrate, not only stimulated the better management and utilisation of grassland by the adoption of systems of rotational grazing but resulted in the development of grass drying as a means of grass conservation and the use of home produced dried grass as an alternative protein concentrate to oil seed cakes. This development not only stood the country in good stead during the lean war years but has aided the farmer materially in his endeavour to make the farm self sufficient in the production of feeding stuffs for his stock particularly during the winter months. As mentioned above, it has only been possible to give the main findings of this research, and for further details those interested should consult the original papers (Woodman, 1929, 1930b, 1935, 1937, 1948 ; Woodman, Bee & Griffith, 1930 ; Woodman, Blunt & Stewart, 1926, 1927 ; Woodman & Evans, 1930, 1938b and c ; Woodman, Evans & Oosthuizen, 1938 ; Woodman & Norman, 1932, 1934 ; Woodman, Norman & Bee, 1928, 1929 ; Woodman, Norman & French, 1931 ; Woodman & Oosthuizen, 1934 ; Woodman & Underwood, 1932). In addition to grass, Woodman and his colleagues published work on the yield, composition and nutritive value of lucerne particularly as affected by systematic cutting at three different stages of growth, and on the nutritive value of dried lucerne meal (Woodman, Evans & Norman 1933, 1934 ; Woodman & Eden, 1935). Contemporaneous with the pasturage investigations a series of studies were undertaken in which the pig was the experimental animal. In 1924 Wood and Woodman described a crate and harness suitable for digestibility studies with swine and reported a digestion trial with barley meal in which they found that the pig's digestive powers were superior to those of the ruminant in the case of N-free extract but inferior for crude fibre and crude fat (Wood & Woodman, 1924). Earlier Woodman, accepting Wood and Adie's classification of wheat offals (Wood & Adie, 1917) had ascertained the digestibility coefficients of broad bran, bran, coarse and fine middlings with sheep (Woodman, 1923b) and in 1925 he reported a determination of the digestibility of coarse middlings with the pig as experimental animal (Woodman, 1925b) and found its capacity for utilisation of the organic matter of middlings to be akin to that of the sheep. In the case of maize he found the capacity of pigs to digest hard unsoaked crushed maize to be akin to that for soaked or cooked maize, but a very definite advantage was demonstrated for maize prepared by a commercial ' flaking ' process, digestibility of the organic matter rising from 86.09% in the case of ordinary maize to 94.39% in the case of the ' flaked ' maize (Woodman, 1925a). Analyses of a series of commercial samples of flaked maize later indicated that this product as presented for sale was fairly uniform in composition (Woodman & Stewart, 1927). Comparison of the utilisation of maize alone with a maize-milk mixture not only indicated complete utilisation of the whole milk by the pig but also indicated an improvement of the ' crude fibre ' digestibility of the maize when milk was fed with it (Woodman, 1925c). The importance of fibre as a digestible nutrient in the diet of farm animals led Woodman to study the mechanism of digestion of cellulose in the rumen. By *in vitro* methods, the breakdown of cellulose by thermophilic bacteria isolated from dung was demonstrated and the occurrence of glucose during this process established. The earlier *in vitro* studies postulated the possibility that the bacterial digestion of cellulose in the rumen resulted in glucose as the main product of absorption by the animal but this hypothesis was abandoned later when it was established that during cellulose digestion by micro-organisms functioning at 37°C. pyruvic acid and lower fatty acids (formic, acetic and butyric) as well as glucose were produced (Woodman, 1927, 1930a ; Woodman & Evans, 1938a ; Woodman & Stewart, 1928, 1932). In addition to the pasture grass and silage studies, considerable attention was paid to the composition and nutritive values of sugar beet and sugar beet products both for sheep and pigs. From these studies it was established that 25lb. sugar beet tops were equivalent in feeding value to 40 lb. of mangolds (Woodman & Bee, 1927); that dried sugar beet pulp should be regarded as a carbohydrate concentrate rather than as a root substitute in sheep feeding, and that the drying of the pulp by factory methods did not depress its digestibility (Woodman, 1928). It was further found that pigs utilised dried sugar beet pulp in a similar manner to ruminants, but the bulkiness of this product when wetted rendered it unsuitable for use in the dietary of pigs intended for early maturity although it was suitable for breeding sows used in moderate amounts (Woodman, Duckham & French, 1929a). The whole sugar beet, suitably grated, could be used in the diet of bacon pigs as a substitute for barley meal to the extent of one quarter of the total ration, the exchange rate being 3½ lb. sugar beet for each pound of barley meal (Woodham, Duckham & French, 1929b). Other miscellaneous feeding stuffs dealt with in the swine studies were tapioca flour and sago pith meal (Woodman, Menzies-Kitchin & Evans, 1931), degermed maize meal (Woodman & Evans, 1932), oats (Woodman, Evans & Menzies-Kitchin, 1932), young pasture grass (Woodman & Evans, 1934), dried grass meal (Woodman & Evans, 1948a) and meat meals of varying fat content (Woodman & Evans, 1937). In the sheep studies the composition and nutritive values of marrow stem kale and thousand head kale (Woodman, Evans & Eden, 1936) were ascertained and new techniques for measuring the appetites of sheep on pasture evolved. (Woodman, Evans & Eden, 1937b). The appetite of sheep as measured by dry matter was found to be less than the T. B. Wood standard and a revised standard given, and the appetite of sheep on pasture found to be greater than that of sheep on winter rations (Woodman, Evans & Eden 1937a).

In 1929 and 1930 Evans described experiments with pregnant sows on high and low calcium rations, using a metabolism crate designed by Woodman. On low calcium diets no effect on the birth weights of the pigling was noted, but lactation was adversely affected and there were some signs of anaemia (Evans, 1929a and b, 1930). In a later communication a mineral mixture suitable for pregnant and lactating sows was given (Evans, 1932). In 1933-34 Dunlop published a new improved method of experimentation for swine nutritional studies whereby individual feeding techniques were introduced (Dunlop, 1933, 1934a) and by its aid he ascertained the optimal calcium, phosphorus and vitamin D requirements of swine (Dunlop, 1935a), and vitamin

A requirements (1934b, 1935c). He further demonstrated the unreliability of liveweight increase *per se* as a measure of the nutritive value of a pig ration owing to variability in the protein and fat deposited (Dunlop, 1935b) and found liver to contain a growth promoting appetite stimulating or " physin " factor (Dunlop, 1935d).

Utilising these techniques Woodman and his colleagues undertook a series of studies of the nutrition of the bacon pig, paying particular attention to the effect of level of protein intake on growth, conformation and quality. High levels of protein in pig rations were found unnecessary (Woodman, Evans, Callow & Wishart, 1936), gilts were found to retain more nitrogen than hogs, high protein diets led to no more retention of nitrogen than normal protein diets, and the daily retention of nitrogen remained approximately constant from weaning up to 200 lb. liveweight (Woodman, Evans & Turpitt, 1937). Later it was found possible to reduce the protein content of bacon pig rations below the customary standard without affecting the efficiency of the ration or the quality of the pig meat, except at liveweights below 90 lb. (Woodman, Evans & Callow, 1939). Using meat meals of widely varying fat content had no measurable effect on the carcase (Woodman & Evans, 1939b) but the oil in fish meal was found to have a softening effect on the carcase fat (Woodman & Evans, 1940a). The minimal levels of protein intake consistent with quick growth and carcase quality are indicated in later communications (Woodman & Evans, 1941, 1945b) and latterly the very important question of the supplemental value of proteins of various origins has and is receiving attention (Woodman & Evans, 1948b).

With the outbreak of war in 1939 Woodman and his colleagues turned their attention to short term problems of wartime importance. The use of swill for pig feeding received early attention both unprocessed and in a concentrated form, and the values of winter and summer types of swill ascertained (Woodman & Evans, 1942, 1944b). Pigs were found to utilise dried potato products (potato cossettes, potato flakes, potato slices, potato dust, potato meal) more efficiently than sheep (Woodman & Evans, 1939a, 1943a), the value of pea-pod meal and broad bean pod meal for feeding to ruminants was ascertained (Woodman & Evans, 1940b) followed later by reports on the nutritive value for sheep of pea-canning by-products (green pea pods, pea pod meal, pea pod silage and molassed silage). As compared with sheep, pea pods (steamed) had a poor value for pigs (Woodman & Evans, 1944c), and whereas potato flakes were the best form of dried potato products for pig feeding, potato slices or cossettes were considered best for sheep and cattle. Cooked potatoes were also shown to be a suitable *ad lib.* bulky supplemental food for bacon pigs fed on the Lehmann system in which a fixed daily allowance of pig meal is given, but molassed beet pulp was not so satisfactory (Woodman & Evans, 1943d). Cooked potato peelings also proved a satisfactory pig food, 5 lb. of peelings being equivalent to 4 lb. of potatoes (Woodman & Evans, 1943b). The higher extraction rate of flour and the inclusion of barley in the grist also affected the nature and composition of wheat offals and the effect of these changes on the nutritive value received attention (Woodman & Evans, 1944a).

Wallace has reported that allowing young pigs access to pasture in a young state of growth might lead to a daily saving of .4 to .7 lb. of meal per pig (Wallace, 1943) but Woodman and Evans found that the practice of *ad lib.* feeding of grass cuttings to pigs on a limited pig meal allowance was not suitable for bacon pig production (Woodman & Evans, 1943c).

The extent to which palm kernel meal should enter into pig rations was also studied for bacon pig production (Woodman & Evans, 1945a) and the value of discarded ryegrass seed meal, clover seed meal, lucerne seed meal and sainfoin seed meal ascertained. These latter products if finely ground were considered suitable for addition to feeding compounds (Woodman & Evans, 1947d).

Two unusual products, fodder cellulose manufactured from wheat straw and dried penicillin felts arising from penicillin production were studied. Dried penicillin felt was considered to be suitable as a partial substitute for oil cake in cattle and sheep rations (Woodman & Evans, 1947) and fodder cellulose was found to be unsuitable for pig feeding but suitable for cattle and sheep (Woodman & Evans, 1947a and b). Horse chestnut residues arising in the extraction of saponin and the manufacture of glucose from horse chestnuts were found to have but little feeding value for sheep and pigs, but water extracted and alcohol extracted horse chestnut meal was considered suitable during times of scarcity if used in moderation (Woodman and Evans, 1946a and b).

In 1923 the scheme of research was enlarged to include poultry and the writer who had joined the Ministry of Agriculture shortly after the Great War resigned his post to take charge of this branch of the work at Cambridge. The field was an attractive one, little was known of the nutritional needs of poultry, and the Poultry Industry was eager for guidance on the correct feeding of poultry under the newer systems of poultry management that were coming into being. Accordingly the work at Cambridge had as its main object the evolution of a scientific basis upon which standards for the feeding and fattening of poultry could be established and the acquisition of knowledge on the nutritional factors affecting the quality of eggs and poultry meat. An analytical study on the changes in carcase composition occurring during growth of a typical egg-laying breed, the White Leghorn and a typical meat breed, the Light Sussex, gave data upon which estimates of food requirements during various stages of growth could be based and in 1939 a tentative standard for the maintenance and production requirements for egg production was published (Halnan, 1929, 1930a). During 1929-31 in collaboration with Mr. J. W. Dallas, Agricultural Organiser for Bedfordshire, accurate records of food consumption and egg production of birds in a County Egg Laying Trial were obtained and treated statistically and analysed by the method of least squares. The data so obtained enabled revised standards to be given (Halnan, 1934). Commercial application of these standards while corroborating the correctness of the standard for energy requirements gave indications that the protein standards were on the generous side and a re-investigation of the protein requirements of the egg producing fowl, involving field trials under confinement conditions, nitrogen metabolic studies and digestibility trials was undertaken during 1936 and 1937 and a revised standard published in 1939 (Halnan. 1939). These revised standards suitable for application to English feeding conditions are in general use in this country (Halnan, 1949). Parallel with these investigations on the protein and energy

requirements of the laying fowl a series of digestibility trials on the commoner poultry feeding stuffs was undertaken and included the following :—Yeoman II wheat, Little Joss Wheat (Halnan, 1926), Swedish Iron wheat, Bearded Rivett wheat, whole and flaked maize (Halnan, 1928a), Grey Winter, Black Bountiful and Scotch Potato oats, and Bulrush millet (Halnan, 1928b), broad bran, straight run middlings, fine middlings and dried molassed sugar beet pulp (Halnan, 1937), wartime fine and coarse brans (Halnan, 1944a), raw and cooked potatoes, potato flakes, dried potato slices and dried potato shreds (Halnan, 1944b) and sunflower seeds (Halnan, 1943). It was further established that, within the limit of appetite of the fowl, varying the daily intake of a ration had no effect on the digestibility of the food (Halnan, 1928c) and woody fibre was proved to be of little or no importance as a digestible nutrient in poultry rations (Halnan, 1930b). Indeed, where the fibre was a natural constituent of the food such as oats, evidence was obtained that high fibre tended to depress the digestibility of the other naturally occurring ingredients (Halnan, 1928b).

On the fattening of fowls Southgate ascertained the maintenance requirement for energy of the fattening cockerel and published a novel chemical method for the calculation of the surface area of the body (Southgate, 1930). This was followed later by a note on the starch equivalent required to produce 1 lb. live weight increase during trough feeding and cramming (Halnan, 1935) and a study on the relative efficiency of food conversion to edible meat production of birds fed to different weights, in which it was established that the 3½ lb. cockerel and the 4 lb. pullet of the Light Sussex breed yielded the highest proportion of edible meat in relation to food consumed (Halnan & Fermor, 1937). It was further established that the protein level of poultry fattening mixtures could be considerably reduced without adversely affecting the efficiency of conversion of food energy to carcase energy (Halnan, 1938a), and later by studying the carcase composition of a number of cockerels of the same age group it was shown that the big variable in carcase composition is the fat, the protein—ash ratio in a breed remaining practically constant after the age of 7 weeks (Halnan, 1938b). On the quality of poultry meat much attention was given to a study of the conditions governing the deposition and composition of fat in the bird. It had already been noted that marked differences existed between the sexes in their capacity to store fat (Halnan & Cruickshank, 1933) and palm oil had been shown to be a suitable substitute for mutton fat in fattening mixtures (Halnan & Cruickshank, 1932). Maize meal was further found to lead to the deposition of a firm fat in the fattening cockerel (Cruickshank 1937). Cruickshank by a series of well designed experiments established the fact that the composition of the fat of the diet influenced the composition of the body fat, a hard or saturated food fat giving rise to a hard body fat, similarly a soft food fat gave rise to a soft body fat. In the case of egg fat, however, it was found that whereas the feeding of highly unsaturated fats to the laying fowl resulted in a rise in the iodine value of the yolk fat of eggs laid, the feeding of saturated fats did not reduce the iodine value of the yolk fat below a threshold value which was considerably higher than that of the saturated food fat itself (Cruickshank, 1932, 1934a and b). It was further found that birds could tolerate levels of fish meal much higher than those normally fed without causing taint in either carcase or egg (Cruickshank, 1939).

A study on the nature and cause of various egg defects led to the conclusion that most common egg faults were normally associated with the individual hen rather than with nutritive conditions (Halnan & Day, 1938). The mechanism of infection of eggs by bacteria and fungi was demonstrated in a study of " black spot " in eggs (Weston & Halnan, 1927) and later, a troublesome outbreak of " black rot " in imported eggs was found to be due to an hitherto unidentified micro-organism, *Proteus melanovogenes* (Miles, 1937).

In endocrine studies a seasonal variation in the weight and iodine content of the thyroid was noted (Cruickshank, 1939). Feeding iodine rich substances markedly increased the iodine content of the thyroid, and both the thyroid weight and iodine content were found to increase in proportion to the body weight of the growing bird, reaching a maximum at sexual maturity (Cruickshank, 1930).

In a study on the biological value of two varieties of whale meat meal the effect of protein in increasing the efficiency of a ration as judged by liveweight increase was clearly demonstrated (Halnan, 1942a) and it was noted that the incidence of the condition known as ' gizzard erosion ' in chicks on a certain diet was closely correlated with the growth rate (Halnan, 1942b). The feeding of vitamin A supplements to laying fowls resulted in an increase in the Vitamin A content of the egg (Cruickshank & Moore, 1937). The value and use of mineral supplements both for growth and egg production received comprehensive treatment and the conclusion was reached that the only supplementation needed by the growing chick and laying fowl on normal rations is common salt and calcium carbonate (Halnan, 1936).

With the outbreak of war in 1939, the problem of supply of food for poultry became acute and the depleted staff turned their attention to the use of substitute foods. Among the problems studied, the potential value of sunflower seeds, edible household waste, wartime milling offals, green vegetables and potatoes as poultry foods was ascertained. Sunflower seeds were shown to be equivalent to wheat in feeding value for energy purposes and double the value so far as yield of protein was concerned (Halnan, 1943). Cooked edible household waste was found to be suitable for use for egg production fed at the rate of 6 oz. to 8 oz. of cooked waste to 2 oz. of a suitable cereal and protein balancer meal (Hunt, Halnan, Pease & Page, 1943). The effects of changes in milling practice on the nutritive value of wheat offals for poultry were studied. The wheat offals consisted of fine and coarse bran and whereas the fine bran from wheat grist was equal in value to pre-war bran, the coarse bran was distinctly inferior, as was fine bran derived from a wheat-barley grist (Halnan, 1944a). Green vegetables owing to their bulky and watery character proved unsuitable for inclusion in chick or egg production diets but cooked potatoes proved very suitable as a cereal substitute both in chick and egg production rations, satisfactory growth and egg production being obtained on rations in which half the dry matter content consisted of potato (Halnan & Fermor, 1942). Cooking the potatoes was found to be essential for economical use, 1 lb. of cooked potatoes yielding as much available energy to the fowl as 5 lb. of

uncooked potatoes (Halnan, 1944). The possible saving in poultry food by using grass and other green vegetable foods was estimated to be from 5 to 10% in the fowl, 16 to 18% in the case of turkeys and ducks, and 100 % in the case of the goose (Halnan, 1948a).

Finally, urea and ammonium compounds, which in the case of the ruminant had been shown to be effective under certain conditions as a protein substitute, were definitely shown to be ineffective in the case of the fowl (Halnan, 1948b).

In conclusion a few words on the methods whereby the practical findings of these researches were brought to the farmers' notice may not be out of place. Starting in March 1915 a popular article later called *Notes on Feeding Stuffs* was published monthly in the Journal of the Ministry of Agriculture and served as a medium for educating the farmer into the newer methods of feeding practice and calling his attention to modern developments. This column was under the authorship of T. B. Wood until 1920, under the writer from 1920 to 1927, from 1927 to 1929 under the authorship of H. E. Woodman and then under H. G. Sanders until Cambridge ceased responsibility for this column in 1931. The newer methods of the rationing of farmers livestock were first expounded in *The Composition and Nutritive Value of Feeding Stuffs* a book written by T. B. Wood and the writer and published by the Cambridge University Press in 1918. At the request of the Ministry these authors surrendered their copyright and the book reappeared as a Bulletin of the Ministry of Agriculture entitled *Rations for Livestock*, first under the authorship of T. B. Wood and since his death under the authorship of H. E. Woodman. A similar publicity method was adopted for poultry, a bulletin of the Ministry of Agriculture on *Scientific Principles of Poultry Feeding* appearing in 1930 under the authorship of the writer. Both these bulletins have proved very popular and have run through many editions.

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AGRICULTURAL ECONOMICS

Changes in the Economic Organisation of Agriculture. A Comparative Study of Conditions in the Eastern Counties of England between an Identical Sample of Farms in 1947–48.
Fm Econ. Br. Rep. No. 33. 1949. Pp. 32. Price 5*s.*

The financial returns of 400 farms are compared for the years 1948 and 1947. The farms are the same in both years and are divided equally between ten " type of farming " districts within the Province. In each of these areas profits in 1948 were appreciably higher than in 1947, when returns were at a particularly low level. Overall, the profit surplus amounted to £5 14*s.* 4*d.* per acre in 1948 as compared with only 5*s.* 7*d.* per acre in 1947. All districts showed a substantial surplus in 1948 whereas in 1947 the returns in six of these areas were insufficient to remunerate the farmers for their work and provide interest on the capital invested.

Weather conditions differed greatly between the two years. In 1947 crops had a very late start and suffered greatly from subsequent drought, but those of 1948 were sown under ideal conditions and made continuous growth throughout a wet summer. As a result, hay crops in the latter season were of poor quality, and the corn harvest was rendered difficult by extensive lodging and wet weather. Nevertheless, in the words of a West Cambridge farmer, 1948 " was a bumper year—one of a lifetime ". High crop yields were general, and income from this source rose by £6 5*s.* 0*d.* per acre, and was alone sufficient to account for the increase in net returns.

Altogether gross income rose by 34 per cent. between the two years, ranging from an increase of 18 per cent. in the Holland Silt district to one of 53 per cent. in Central Norfolk. This was mainly due to the higher crop yields, but there was also some rise in commodity prices. The returns from milk and livestock rose by 13 per cent. over the whole sample, while the increase from crops amounted to 47 per cent.

Overall gross charges in 1948 were 9 per cent. higher than in 1947, ranging from a rise of 5 per cent. in Huntingdon and West Cambridge to one of 16 per cent. in Central Suffolk. Minimum wage and National Insurance rates rose by about 10 per cent. between the two years and though there was some reduction in employment the total cost of labour on these farms rose by 6 per cent. The outlay on foods, seeds, fertilisers and tackle hire rose substantially while numerous other items shared to some extent in this upward trend.

Comparing the two years the value of the gross output on these 400 farms increased by 36 per cent.—a result which was due almost entirely to greater production, for the volume of output increased by about 32 per cent. This, however, was mainly the outcome of seasonal differences beyond the control of the human element.

Labour Requirements in Milk Production.
Fm Econ. Br. Rep. No. 32. 1949. Pp. 39. Price 5*s.*

This report is based on the results of a survey carried out on 140 dairy farms. No finality is claimed for the results obtained and there is room for much further experiment. Hardly any research on job analysis has been carried out in Britain and it would appear that a repetitive task such as milk production is an ideal subject for such an enquiry. The present purpose is to show the " average " amount of labour required against which the individual farmer can check his own performance ; to suggest a technique whereby work performance can be measured ; to analyse some of the principles on which routine may be designed and show by example how much variation can occur in practice. These variations are important from a financial point of view. To take an example, farms D.3 and D.7, quoted earlier, had tuberculin tested herds of the same breed, similar buildings and approximately the same yield per cow. Yet one required 203 hours labour per cow and the other only 83 hours. The difference of 120 hours (at 2/6 per hour) is equivalent to £15 per cow, or, for a herd of 60 cows, £900 per year.

One criticism of job analysis may be anticipated : that it places too much emphasis on speed. By itself speed cannot be regarded as a criterion of success. Milking cows is a skilled operation and if the individual worker is merely " speeded up ", the quality of his work may suffer. The purpose of job analysis is therefore not the speeding up of individual operations, but rather the elimination of unnecessary movement so that more work can be done with less fatigue.

To summarise the results obtained, the following are some of the salient points :

1. Taking first the cowshed system, it was shown that large herds tended to use less labour per cow than small herds.
2. Machine milked herds used less labour than hand milked herds, a saving which covered the cost of the machine by a substantial margin. Indeed, there is evidence that the use of a machine may be justified in a herd as small as 10 cows.
3. Cows kept in yards used significantly less labour than those kept in a cowshed. The saving was greatest for cows kept in a walk-through parlour which required on the average 43 man-hours, or 24 per cent. less labour than those in a cowshed. The " yard and cowshed " group showed results intermediate between the cowshed and the yard and parlour groups.
4. An examination of individual results showed a considerable variation in each group, due to differences in work routine and convenience of buildings. To evaluate these factors separately, a detailed study was therefore made of milking which alone accounted for 40 per cent. to 55 per cent. of the time spent on cows.
5. To examine work routine, the technique of job analysis was employed. This includes the recording of the order in which operations are carried out, the time taken and the distance travelled.

6. An attempt was then made to formulate the general principles on which a good routine should be designed, and in particular to link this with the quick milking routine. Suitable routines were suggested for the cowshed, the walk-through parlour and the tandem two-level parlour. These principles were illustrated by observations made on various farms.
7. The effect of different types of buildings was then estimated by using a standardised routine in cowsheds of various designs. This showed that the distance per cow increases sharply with increase in the size of house. The distance travelled is also substantially greater if the dairy is placed at one end of a large house instead of in the middle, or if a single row house is used instead of a double row house. The design of yards for use with a milking parlour was also considered.
8. Finally, the advantages and disadvantages of the milking parlour system in comparison with the orthodox cowshed were summarised.

To conclude, it is hoped that this report may stimulate discussion and experiment. The tending of dairy cows employs more labour than any other single operation in farming and any saving of the man-hours required will not only reduce the cost of producing milk but will ensure the best use is made of the skilled man power available.

A Survey of the Cost of Producing Potatoes in Two Districts in the Eastern Counties, 1947.†
Fm Econ. Br. Mimeog. Rep. No. 36. 1948.

A Survey of the Cost of Producing Sugar Beet in Three Districts in the Eastern Counties, 1948.
Fm Econ. Br. Mimeog. Rep. No. 37. 1949.

A Survey of the Cost of Growing Linseed in Two Districts in the Eastern Counties, 1948.
Fm Econ. Br. Mimeog. Rep. No. 38. 1949.

A Survey of the Cost of Producing Wheat in Three Districts in the Eastern Counties, 1948.
Fm Econ. Br. Mimeog. Rep. No. 39. 1949.

ENGLEDOW, F. L.
Agricultural Production in the Early Future : Second Interim Report of Southern Rhodesia Development Co-ordinating Commission, Feb., 1949.
Price 1*s.* (*obtainable from the Government Stationery Office, Salisbury, S. Rhodesia*).

A commentary on a Five-Year Plan for Agricultural Production by the Department of Agriculture, Southern Rhodesia, and dealing with topics which include soil erosion, labour supply and efficiency, mechanisation, and the requirements and possibilities of production of the staple foods of the country, and particularly maize, meat and dairy products.

ENGLEDOW, F. L.
Report on Agricultural Teaching, Research and Advisory Work. February, 1949.
(*Government Stationery Office, Salisbury, S. Rhodesia*).

A review of the physical, economic and other circumstances necessary to be taken into account in making proposals for the development of teaching, research and advisory work for Agriculture in Southern Rhodesia, with detailed recommendations for this development.

STURROCK, F. G.
Labour Organisation in Milk Production.
Home Fmr. 1949, **16**(8), 14–16, (9), 10–12, (10), 14–15.

AGRICULTURAL ZOOLOGY (including Entomology)

LEACH, R.
Nutfall in the Solomons.
Progress. 1949, **40**(223), 18–22.

At the invitation of Unilever Bros. and Unilever Ltd. a visit was made to the British Solomon Islands Protectorate in 1948 to report on the premature nutfall of coconuts, previously known to be caused by the sucking bug, *Amblypelta cocophaga*. The investigation was carried out in co-operation with B. A. O'Connor, Government Entomologist, Fiji.

Earlier work had indicated that, between the two World Wars, the increase of this devastating trouble was due to the invasion of the coconut plantations by the ants, *Pheidole oceanica* and *Iridomyrmex myrmecodiae*. These were considered to have driven out the beneficial yellow tree-ant, *Oecophylla smaragvina subnitidae*, which keeps *Amblypelta* off the palms. The two smaller ants do not disturb the sucking bug so that their invasion of the plantations resulted in an increase of nutfall.

By studying the incidence and symptoms of nutfall in the affected plantations on Guadalcanal, evidence was obtained showing that since 1945 there had been a remarkable amount of natural recovery from nutfall. This occurred only in plantations previously occupied by *Pheidole*.

† *Continuation of the War Series Reports. Obtainable from the Farm Economics Branch.*

Between the two wars the bases of the palms were kept free of weed growth in order to facilitate harvesting the coconuts. This had unwittingly encouraged the establishment of *Pheidole* which nest freely in the aerial roots at the base of the palms and, by so doing, readily capture the beneficial *Oecophylla* travelling to and from the ground on the palms. Since 1945, when extensive military camps were situated in the plantations, the latter have become overgrown with vegetation including various creeping vines. *Oecophylla* has been able to take advantage of these changed oecological conditions by reaching the palms along the more hairless vines, thus avoiding the strongholds of *Pheidole* in the aerial roots at the base of the palms. Wherever *Oecophylla* has re-occupied palms nutfall no longer occurs, and on recently occupied palms there is no evidence of the typical *Amblypelta* feeding scars to be seen on the youngest nuts.

No recovery had occurred in the plantations invaded by *Iridomyrex*, presumably because the latter is found in great strength all over the palms so that the vines have been of no avail to *Oecophylla*. Strikingly enough the only palms on which *Oecophylla* was established in the *Iridomyrmex* areas were those which had *Pheidole* present in the base of the palms, apparently warding off the *Iridomyrmex* while *Oecophylla* was taking advantage of the vine growth.

It is anticipated that recovery from nutfall can be maintained provided that methods of plantation management do not permit pre-war conditions to recur. Control of nutfall in the *Iridomyrmex* areas may yet be attained either by direct chemical means or by the introduction of predators against *Amblypelta*.

AGRICULTURE

967* Hanley, F.
The Fenlands.
Agriculture : J. Minist. Agric. 1949, **56,** 214–20.

ANIMAL BREEDING AND GENETICS

Cock, A. G.
Two Cases of Lateral Asymmetry in the Fowl.
Heredity. 1949, **3,** 262.

The left side of the first case, a pullet *ex* Rhode Island Red × Light Sussex, is about 12 per cent. (linearly) smaller than the right, and has a yellow shank (*w*) and frayed flight feathers, probably due to the gene " fray " (*fy*). The right side has paler feathers and carries *W* and *Fy*. The *W* and *Fy* loci are almost certainly on different chromosomes. The small side is abnormal in shape, the large side normal. This conflicts with the theory that half-siders are due to non-disjunction or elimination of an autosome at first cleavage, according as the size-differential is respectively 10—15 per cent. or about 3 per cent. The genitalia were diseased but otherwise normal.

The second case is still under observation. It is heterozygous for at least three known autosomal genes, but the only abnormality apparent is a lateral size-differential of about 5 per cent. in the length of the legs.

966* Yeates, N. T. M.
The Breeding Season of the Sheep with particular reference to its Modification by Artificial Means using Light.
J. Agric. Sci. 1949, **39,** 1–43.

The seasonal changes in length of day determine the time of year at which grade Suffolk ewes experience their sexual season under natural conditions in Cambridge, England. It is probable that this finding applies generally to seasonal breeding sheep in all regions.

The natural sexual season (which embraces the autumn and winter months), may be modified and even reversed at will by suitable artificial alteration of the daily light ration.

In grade Suffolk ewes, the onset of the sexual season is a response to decreasing daily amounts of light and occurs 13—16 weeks after the change from increasing to decreasing length of day.

In the same sheep, the cessation of the sexual season is a response to increasing daily amounts of light and occurs 14–19 weeks after the change from decreasing to increasing length of day.

These responses occur irrespective of the level at which the changeover in trend of daily lighting occurs, and are also unrelated to specific ' threshold ' amounts of light.

An understanding of the above principles makes possible an explanation of the seemingly conflicting reports of the responses of British breeds of sheep transported at different times of the year to the southern hemisphere. The most suitable time of the year for making such a transfer can then, theoretically, be recommended.

The length of the dioestrous interval and the duration of pregnancy are not affected by reversal of the sexual season by artificial means.

The establishment of the controlling role of light in regulating the sexual season of ewes, does not rule out the possibility of other stimuli acting to modify it. But of the other factors considered, critical evidence supports only nutrition as having slight effect under specific conditions. The suggestion that an ' inherent rhythm ' of alternate periods of reproductive activity and quiescence operates in sheep, does not receive support.

Sheep show a gradation in length of sexual season according, in general, to the latitude of their place of origin. Thus, sheep indigenous to countries in high latitudes have a shorter and more marked sexual season than those originating nearer the tropics. This variation has probably been brought about by natural selection.

Under natural conditions, the ability of ewes of a particular breed to produce two crops of lambs in a year, depends on the duration of the sexual season and the length of the lactation anoestrum.

Lactation anoestrum apparently varies in length between breeds, but even within a breed, its duration depends on the time of year of parturition. Should lambing occur at the height of the sexual season, the lactation anoestrum may be almost non-existent.

Seasonal variation in fertility of rams also appears to be controlled by the light environment, and the summer decline in libido and semen quality which occurs under natural conditions may be replaced by a period of high fertility following artificial reversal of the seasonal light conditions.

The anterior pituitary is recognised as the organ activated by the light stimulus. Light impulses are received by the eye, from which they are probably passed to the hypothalamus along neural pathways, final transmission to the pituitary being possibly by humoral means, via the hypophysial portal vessels.

For the experimental modification of sexual season, the intensity of artificial light employed is thought to be unimportant once a certain, relatively low, candle-power is reached. White light of an average intensity of about 10 f.c. is quite adequate for sheep, and somewhat lower intensities would probably be equally effective.

Among birds and mammals which react to light, it appears that the type of light treatment administered influences the rapidity and duration of the subject's response.

Some artificial light treatments apparently induce reproductive changes more rapidly than they occur naturally. Whether these are ' emphasized ' effects of the natural environment, or are particularly potent purely by chance is not known. Rapidly induced changes may not be conducive to complete normality of function.

Insufficient attention has been paid, in the past, to the long-term effects of any light treatment, and it is emphasized that where added light is given during the short days, diminished light may require to be provided during the long days to ensure the harmonious functioning of the animal over a long period.

Moulting in birds and the seasonal shedding of hair in animals have been shown to be affected by the light environment. It is possible then, that other functions, too, are regulated by seasonal changes in light.

Animals which originate in areas of high latitude when transferred to the tropics, may be incapable of functioning normally in an environment in which light remains relatively constant, and so would fail to thrive (as observed in British breeds of cattle).

Any immediate practical applications of these experiments are probably limited, since housing of the sheep would be involved. However, the knowledge that the sexual season of sheep is controlled by seasonal changes in the light environment helps to explain certain problems of fertility, and it may serve as a basis for future studies in reproductive physiology of sheep.

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970* HAMMOND, J. **Breeding Better British Livestock.** Contr. to *Management in Farming, Winchester.* 1949, pp. 58–68.
HAMMOND, J. **Improvement of British Cattle.** *Farming.* 1949, **3,** 102–105.
HAMMOND, J. **The Proven Bull.** *Shorthorn. J.* March, 1949, 114.
961* PEASE, M. S. **A Genetic Jig-saw Puzzle.** *Autosex. Annu.* 1949, 6–8, 19.
PEASE, M. S. **New Autosexing Breeds.** *Autosex. Annu.* 1949, 25–27, 33.

ANIMAL NUTRITION

HALNAN, E. T. & GARNER, F. H.
Alimentación y Crianza del Ganado.
Buenos Aires, 1948.

This first Argentine edition of the book by Halnan and Garner on the " Principles and Practice of Feeding Farm Animals " has been translated from the second English edition.

973* POMEROY, R. W.
Review of Pig Experimental Work at Cambridge, 1940–1948.
Pig. Breed. Gaz. 1949, **58,** 69–74.

964* WOODMAN, H. E.
Ensilage, with particular reference to the A.I.V. Process.
Agriculture : J. Minist. Agric. 1949, **55,** 513–7.

ANIMAL PHYSIOLOGY

983* WALTON, A.
The Effect of Egg-yolk and its Constituents on the Respiratory Activity of Bull Spermatozoa.
Union Intern. Sci. Biol. Ser. B. 1949, **3,** 40–45.

Egg-yolk has been shown to have a number of different effects upon respiratory activity of bull spermatozoa. In the dialysable fraction of the yolk there are present (a) substances which affect a transitory activation. These have not been further investigated. (b) Amino-acids which give rise to inhibitory concentrations of H_2O_2 formed by oxydative deamination by the spermatozoa. The ether soluble fraction supports respiration but proof that lipoid material is utilised as a substrate for metabolism has not yet been obtained. The ether soluble but acetone insoluble fraction gives complete protection against " temperature-shock ". Fresh egg-yolk and the non dialysable fraction protect the spermatozoa from the " dilution effect ".

OTHER PAPERS

WALTON, A. **Physiology of the Dairy Cow. II-VI.** *Home Fmr.* 1948, **15** (11), 16 ; (12), 22–23 ; 1949, **16**(1), 12–13 ; (2), 20–21 ; (3), 20.

ANIMAL PRODUCTION

960* WALLACE, L. R.

The Growth of Lambs before and after Birth in Relation to the Level of Nutrition. Part III.
J. Agric. Sci. 1948, **38**, 367–401.

The effect of imposing two extreme levels of diet upon the pregnant ewe during two periods, one of early and one of late, gestation was studied. Some ewes were fed on high and some on low planes of nutrition from the 28th day of pregnancy until term, while in others the level of diet was reversed after 91 days. Representative ewes from each group were killed at 91 — 144 days. The differences between the treatments to which the animals were subjected were found to have markedly influenced the conditions of the ewes ; during periods of high-plane feeding, in both early and late gestation, they made substantial live-weight gains, while on the poor diet considerable losses in live weight occurred.

The differences in their live weights were found to have resulted both from changes in the carcass and in the organs and offal parts. It was seen, however, that all parts of the body were not penalized or encouraged to the same extent.

In both well- and ill-fed ewes, the gravid genital tract and the udder continued to increase in weight throughout pregnancy, and the results obtained demonstrate quite strikingly the astonishing ability of the gravid uterus to continue its growth, not only at the expense of the mother's accumulated reserves, but even when her vital structures are being depleted and she is reduced to a state of extreme emaciation. This, however, does not mean that the level of nutrition is unimportant for the development of the foetus, for it was found that the extent of the weight increase made by the gravid uterus was very profoundly affected by the level of feeding during the later months of pregnancy, although the treatment of the ewe before 91 days had no appreciable effect. In connection with these findings it appears that it is the level of nutrition actually prevailing during the period over which the gravid uterus is making its maximum growth that is important rather than the state of the body reserves of the mother at that time. Thus, on the one hand, it was found that, provided the ewes were fed upon a liberal diet over the last months of pregnancy, the gains made by their gravid uteri were equally great whether the animals had started this period with well-stocked or with depleted bodily reserves. On the other hand it was equally apparent that the extent to which the growth of the genital tract was retarded by ill-feeding during these months was not governed by the bodily conditions of the ewe, for the retardation was as marked in those which had been well fed during the early months as in those ill fed for the whole of pregnancy.

When the growth made by the foetus itself is examined it is seen that the difference between those from well- and ill-fed ewes is not merely one of absolute weight attained, but that the poor nutritive régime has had the effect of slowing the growth of some parts more than that of others. On the other hand, the differential response seen between the various tissues fully confirms the need for animals to be reared under optimum nutritive conditions if differences between them in respect to their fleshing qualities are to be assessed.

OTHER PAPERS

HAMMOND, J. **How England and Wales Developed A.I. in Cattle.** *Farm : Pig Breed. Soc. S.Africa.* 1948, **1** (11), 2–5.

PLANT BREEDING AND GENETICS

955* BELL, G. D. H.

Developments in Cereal Breeding.
J. Inst. Corn Agric. Merchants. 1948, **1**, 155–69.

A popular account of the development of the methods and techniques of cereal breeding with examples of practical achievements in Britain in terms of new and improved varieties which have been introduced to British agriculture as a result of plant breeders' efforts.

975* HOWARD, H. W.

Crops and Plant Breeding.
J. R. Agric. Soc. 1948, **109**, 1–12.

The section titles in this annual review article are :—British Plant Breeding Institutes, National Institute of Agricultural Botany, Grassland Research, Flax and Linseed, Sugar Beet and Mangolds, Wheat, Barley, Isolation Requirements of Seed Crops, and Potatoes. The section on potatoes is the largest and deals with consumption, new varieties, virus diseases, dry rot, storage and sprout-inhibiting chemicals, quality, blight, and photoperiodic requirements.

971* HUNTER, H. & CARSON, G. P.

The Breeding History of Picton Oats and Observations on the Behaviour of Certain Oat Crosses.
J. Agric. Sci. 1949, **39**, 119–24.

The origin and behaviour of the " *ex* 109/1 series ", from which the winter variety Picton was selected, are described in detail. The appearance of the anomalous grey grained character in a plot of 109/1, a white-grained segregate of Argentine × Grey Winter, is attributed to out pollination. Erect spikelets and " grass clump " habit occurred in the " 85 series ", originating from a black grained rogue in culture 109/1/5. The former probably arose through the deletion of a small portion of a chromosome. Anomalous breeding results have only occurred in crosses between varieties of the winter and spring groups. The view is expressed that possibly winter varieties classified as *Avena sativa* are in reality derivatives of hybridizations between *A. sativa* and *A. byzantina*. On this assumption a new approach to breeding for winter hardiness is possible.

Salaman, R. N. & Hawkes, J. G.

The Character of the Early European Potato.

J. Linn. Soc. Lond., Bot. 1948–9, **161,** 71–84.

In a previous study of a large collection of cultivated potatoes from South America, the senior author classified varieties of *Solanum andigenum* into six different intergrading groups on the basis of leaf characters and found that as the distance from the assumed centre of distribution of *S. andigenum,* viz. the Andean region of Titicaca, increased in a northerly or southerly direction the greater was the proportion of those forms whose leaf characters approximated more closely to that of European domestic varieties; the view was accordingly expressed that *S. tuberosum* varieties are specialized forms of *S. andigenum.*

The examination of European herbarium specimens preserved during the period 1600 to 1750, on the basis of a similar analysis of leaf characters as that used in the study of the South American potatoes, has provided evidence that the earliest types of potato grown in western continental Europe and England were typical of *S. andigenum,* that new varieties were continually being raised from true seed, and that by selection forms were cultivated in which a larger and more condensed type of leaf borne by a stouter stem, characteristic of the modern potato, was evolved. By selection *S. andigenum* has thus been converted in *S. tuberosum.* This process appears to have proceeded rather more rapidly and at an earlier date in England than western continental Europe.

OTHER PAPERS

Ashton, T. **Better Crops Through Hybrid Seed.** *World Crops.* 1949, **1,** 51–4.
Ashton, T. **Plant Breeding and Better Food Crops.** *Biol. & Human Affairs.* 1949, **14,** 171–77.

PLANT PATHOLOGY

958* Dickinson, S.

Studies in the Physiology of Obligate Parasitism. I. The Stimuli Determining the Direction of Growth of the Germ-tubes of Rust and Mildew Spores.

Ann. Bot., N.S. 1949, **13,** 89–104.

The germ-tubes of rusts and powdery mildews grow sometimes along and sometimes away from the surface on which the spores have germinated. They grow away from the surface of water, and away from or along the surface of collodion or gelatin membranes according to the adjustment of the humidity gradient. When precautions are taken to prevent humidity gradients, the direction of growth with collodion or gelatin membranes is either along or away from the surface according to the previous treatment of the membranes.

The direction of growth of the germ-tubes of downy mildews is similar to that of rusts and powdery mildews, except when germinated on water, when they grow beneath the surface. It is suggested that this difference is due to the fact that the spores of downy mildews are more easily wetted than those of rusts and powdery mildews.

It is concluded that the tropisms controlling the direction of growth of the germ-tubes are positive hydrotropism and two types of growth response due to contact; these are termed negative thigmotropism (growth away from a surface) and dia-thigmotropism (growth along a surface).

It is suggested that for the artificial culture of these obligate parasites a suitable membrane should be interposed between the fungus and the nutrient medium, thus simulating to some extent the system of cell-wall and cell-contents of the host plant.

963* Dickinson, S.

Studies in the Physiology of Obligate Parasitism. II. The Behaviour of the Germ-tubes of Certain Rusts in Contact with Various Membranes.

Ann. Bot., N.S. 1949, **13,** 219–36.

The phenomena, exhibited by the germinating uredospores of three rust fungi as they enter the living host plant, have been observed in germ-tubes growing on specially prepared, artificial membranes. These phenomena—namely formation of appressoria, of substomatal vesicles, and of infection hyphae—are shown to be induced by a contact stimulus. Certain other phenomena, in particular nuclear division, seem also to be the result of a contact stimulus. Infection hyphae of one rust formed on such membranes are shown to produce haustoria in living mesophyll cells of a wheat leaf.

968* Dickinson, S.

Studies in the Physiology of Obligate Parasitism. III. The Growth of Rust Mycelium out of Infected Leaves.

Ann. Bot., N.S. 1949, **13,** 337–43.

Experiments are described which show that on removal of the epidermis, the mycelium of *Puccinia triticina* and *P. graminis* will grow out as tufts of hyphae from infected leaf tissues.

969* Dickinson, S.

Studies in the Physiology of Obligate Parasitism. IV. The Formation on Membranes of Haustoria by Rust Hyphae and Powdery Mildew Germ-tubes.

Ann. Bot., N.S. 1949, **13,** 345–53.

The structures formed after contact and penetration of certain artificial membranes by the mycelium from leaves infected with *Puccinia triticina* and by the germ-tubes of *Erysiphe graminis* are described. The correspondence in method of formation and in size between these structures and the haustoria in the host is very close. It is concluded that these structures are haustoria formed on artificial membranes.

CHILDS, E. C.

The Ghyben-Herzberg Lens.

Proc. 2nd Intern. Conf. Soil Mech. 1948, **6**, 150–53.

When a bank of permeable soil is surrounded by the sea, which may be at different levels on different sides, incident rainfall produces a complex groundwater system comprising a " lens " of fresh water in equilibrium upon deeper salt water. In this paper the method of electric analogues is extended to deal with such problems ; the general nature of the solution is established and a set of particular cases is presented, namely the groundwater configuration (water tables, salt water—fresh water boundary, equipotentials and streamlines) for four different rainfall rates in a bank of rectangular cross section. Such cases are of application to drainage and water supply in such areas as Hawaii and the dune zone of Holland.

974* NICHOLSON, H. H.

Field Drainage and Increased Production.

J. R. Agric. Soc. 1948, **109**, 212–21.

A review of field drainage work carried out in England and Wales with government aid, 1939–1948 ; the type of work in relation to the needs of various classes of land, and to the history of drainage work ; with comments on methods and costs in relation to the objectives in view.

PASQUILL, F.

Eddy Diffusion of Water Vapour and Heat near the Ground.

Proc. Roy. Soc. 'A'. 1949, **198**, 116–40.

An experimental study has been made of the factors involved in the turbulent transport of water vapour and heat in the lowest layer of the atmosphere over well-exposed level grassland. Measurements were made over periods of 1 hr. of the water loss from isolated but otherwise naturally exposed sections of the surface layers of the soil and quantitative arguments advanced for adopting them as a reasonable approximation to the true evaporation loss from the ground surface. The incoming and reflected components of solar radiation, the temperature distribution in the soil down to 16 in. and the vertical profiles of temperature, humidity and wind speed in the air up to a height of 2 m. were observed at the same time, and samples taken to provide necessary data on the physical properties of the soil. The net flux of long-wave radiation was computed from the temperature and humidity structure of the atmosphere as given by the present low-level measurements and routine upper-air soundings. The data prescribed the vertical turbulent flux and the vertical gradients of the water vapour and heat content of the air, from which may be evaluated the vertical components of the eddy diffusivities for water vapour and heat (K_V and K_H) as customarily defined.

In the absence of thermal stratification of the surface air layers K_V is shown to be identical with the eddy diffusivity for momentum (K_m) defined by the explicitly established logarithmic law relating the aerodynamic drag and vertical wind shear over a rough surface. The modification of K_V by unstable and stable thermal stratifications and the rapid decrease of stability influence as the ground surface is approached are both quantitatively demonstrated, and a unique relation between parameters involving K_V, the vertical wind shear and the vertical temperature gradient is indicated. No completely satisfactory *a priori* explanation can as yet be given for the latter relation, though in unstable conditions K_V is found to be identical with K_m computed from a recent wind-profile law which does not involve the temperature gradient explicitly and has only been established in functional form. Direct comparison of K_V and K_H reveals a reasonable approach to equality in stable conditions but shows that the latter coefficient is systematically and substantially the greater in unstable conditions. The latter feature is qualitatively in keeping with recent trends in the theoretical concepts of turbulent transport.

The bearing of the results on the problem of indirectly evaluating natural land evaporation is briefly discussed and attention drawn to the implied superiority of the present ' hydrodynamical ' approach over the classical ' heat-balance ' method.

PASQUILL, F.

A Portable Indicating Apparatus for the Study of Temperature and Humidity Profiles near the Ground.

Quart. J. R. Met. Soc. 1949, **75**, 239–48.

A description is given of a portable distant-indicating apparatus suitable for carrying out critical explorations of the vertical distribution of temperature and humidity near the ground. The apparatus is simple in construction in that considerable use is made of moulded plastic tubes of standard shapes and sizes. Essential instrumental characteristics and some details of manipulation and performance in the field are included.

PASQUILL, F.

Some Estimates of the Amount and Diurnal Variation of Evaporation from a Clayland Pasture in Fair Spring Weather.

Quart. J. R. Met. Soc. 1949, **75**, 249–56.

Attention is drawn to a theoretical formula for evaporation in *adiabatic* conditions, which has been applied generally to the case of a natural land surface by Thornthwaite and Holzman. The formula is $E = \frac{\rho k^2 (q_1 - q_2)(u_2 - u_1)}{(\log_e z_2/z_1)^2}$ where E is the rate of evaporation, q_1, q_2 and u_1, u_2 the specific humidities and wind velocities respectively at heights z_1, z_2, ρ the air density and " k " an aerodynamic constant of magnitude of 0.4.

A recent observational study described elsewhere by the writer has established the validity of the formula in *adiabatic* conditions and provided quantitative data on the errors which would arise on applying it in *non-adiabatic* conditions. A simplified form of the equation is here employed as a justifiable approximation, in terms of near-surface observations of the vertical distribution of wind velocity and vapour pressure, in evaluating the rates of evaporation at hourly intervals over a clayland pasture during a week of fair spring weather. These show a pronounced diurnal variation and the daily water losses evaluated therefrom lie betwen 1·4 and 3·6 mm. Demonstration is provided of the substantial error which could arise if for convenience the formula were to be evaluated in terms of daily mean values of the controlling factors.

OTHER PAPERS

954* HANLEY, F. **The Nutrition and Manuring of Potatoes.** *Farming.* 1949, **3,** 11–15.
964* HANLEY, F. **Phosphate Recovery by Crops.** *Agriculture : J. Minist. Agric.* 1949, **55,** 524–28.
957* HANLEY, F. **The Value and Use of Soil Analysis.** *Farming.* 1949, **3,** 44–49.

STATISTICS

WISHART, J.
Analisis de la Varianza y Covarianza.
Pp. 108. *Madrid : Instituto Nacional de Investigaciones Agronomicas, 1949.*

This book consists of a Spanish translation of the Lectures delivered (in English) by the author at the National Institute of Agronomic Research in the spring of 1947. There are eight chapters. Chapter 1 deals in some detail with the variance ratio distribution which is fundamental to the analysis of variance technique, and provides full mathematical proofs. Chapter 2 develops the analysis of variance as a method of testing for the homogeneity of any number of means, in the single criterion of classification case, and thus incorporates the " Student " test for two means. In Chapter 3 the development is carried through to the familiar randomized blocks and Latin square designs used in agricultural experimentation. Chapter 4 covers the analysis of variance as applied to testing the homogeneity of a set of regression coefficients, and this is followed in Chapter 5 by the straightforward case of analysis of covariance. A number of examples illustrating the technique of covariance analysis are given in Chapter 6, and the method is extended in Chapter 7 to the case of two independent variates, and illustrated. The last chapter deals with a number of general considerations that have to be taken into account in planning field trials, and refers in particular to multiple experiments carried out in different years and places, and to rotation trials.

972* WISHART, J.
Cumulants of Multivariate Multinomial Distributions.
Biometrika. 1949, **36,** 47–58.

Known results for the cumulant recurrence relations for the ordinary (Bernoulli) and negative (Pascal) multinomial distributions in a single variate are quoted and proved. The results are then extended to the corresponding multivariate distributions. The problems are dealt with in full for both distributions in two variates. The reciprocal character of the results makes it only necessary to generalize, for any number of variates, in the case of the Bernoulli distribution. This is done, and the paper concludes with the values of all cumulants up to the fourth order, together with the rules for deriving still higher results from those tabulated.

965* WISHART, J.
The Teaching of Statistics.
J. R. Statist. Soc. 1948, **111,** 212–29.

The Royal Statistical Society issued in 1947 a report on the teaching of statistics in universities and university colleges. At their meeting on 27 April, 1948, the report was the subject of a discussion, opened by the author, who took occasion to summarize the content and recommendations of two similar reports recently issued in the U.S.A. The full discussion appears in this publication.

MISCELLANEOUS

BIFFEN, *Sir* R. H.
Obituary by Sir Frank Engledow.
Camb. Rev. 1949, **71,** 42–3.

BIFFEN, *Sir* R. H.
Obituary by Sir Frank Engledow.
Nature, Lond. 1949, **164,** 305.

MARSHALL, F. H. A.
Obituary by J. Hammond.
Nature, Lond. 1949, **163,** 313.

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BOOKS RECEIVED

AFEA*. **Readings on Agricultural Policy.** Ed. by O. B. Jesness. Pp. 470+6 illus. Blakiston Co., Philadelphia, 1949. $4.75.

AKERMAN, J. & HARRIS, M. **Family Farm Policy.** Pp. xxii+518. Univ. Chicago Press, Chicago, 1947. 22*s.* 6*d.*

BARNES, H. F. **Gall Midges of Economic Importance. Vol. 4.** Pp. 165. Crosby Lockwood, London, 1948. 15*s.*

BATES, G. H. **Weed Control.** Pp. viii+236. Spon, London, 1948. 16*s.*

BUTLER, J. & JONES, S. G. **Plant Pathology.** Pp. xii + 979. Macmillan, London, 1949. 63*s.*

DARLINGTON, C. D. & MATHER, K. **The Elements of Genetics.** Pp. 446. Allen & Unwin, London, 1949. 25*s.*

FREAR, E. H. **Chemistry of Insecticides, Fungicides and Herbicides. 2nd ed.** Pp. x+417. Van Nostrand (Macmillan, London), 1948. 33*s.*

Gloucestershire, Somerset and Wiltshire. A Geographical Analysis. Pp. 12+3 maps. Arrowsmith, Bristol, 1949. 8*s.* 6*d.*

GOODE, J. S. & RUDDUCK, H. B. **Artificial Insemination of Farm Animals in the Soviet Union.** Pp.vi+176. Angus & Robertson Sydney, 1948. 42*s.*

JARY, S. G. **Good Control of Insect Pests.** Pp. xii+216. English Univ. Press, London, 1948. 4*s.* 6*d.*

KELLEY, R. B. **Principles and Methods of Animal Breeding.** Pp. viii+296. Angus & Robertson, Sydney, 1946. 15*s.*

LOWE, L. T. **Students Handbook to Fertilizers and Soils. Rev. ed.** Pp. 111. Littlebury, Worcester, 1949. 8*s.* 6*d.*

MERCER, S. P. **Farm and Garden Seeds. 2nd ed.** Pp. xii+156. Crosby Lockwood, London, 1948. 12*s.* 6*d.*

MOORE, H. I. **Root Crops.** Pp. viii+175. Spon, London, 1948. 14*s.*

Situation in Biological Science. Pp. 631. Collet's, London, 1948. 9*s.* 6*d.*

WESTON, W. A. R. D. **Diseases of Potatoes, Sugar Beet and Legumes.** Pp. viii+86. Longmans, London, 1948. 4*s.*

* AFEA = *American Farm Economic Association.*

LIBRARY LACUNAE

The Librarian would welcome gifts or offers of any of the following items :—

American Society of Animal Production. Record of Proceedings. 1908–1926, 1929–30.

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Bibliography of Agriculture. Washington. Vols. 1–3.

Annales des Épiphyties. Vol. 12. No. 4.

Archief v. Rubbercultuur. Vol. 25. No. 6.

Aslib Book List. Vol. 1, No. 4 ; 6, No. 1 ; 7, No. 3.

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Biological Bulletin. Vol. 53, No. 1.

Bodenkunde u. Pflanzenernährung. Vol. 34, Nos. 3–6 ; 35, Nos. 5–6 ; 36.

Botaničeski Žurnal, U.S.S.R. Vols. 21-22.

Bull. American Soil Survey Assoc. Nos. 1-16.

Bull. Soc. Scient. d'Hygiene Alimentaire. Vol. 31. Nos. 1-3.

Canada. Nat. Res. Council. Bibliography on Soil Mechanics.

Chronica Botanica. Vol. 6. Nos. 3, 5, 14.

English Guernsey Herd Book. Vols. 59, 60.

Farm and Forest (Nigeria). Vol. 2, Nos. 3–4 ; 3, Nos. 1–4 ; 4, Nos. 1–4.; 5, Nos. 1-3.

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Fecondazione Artificiale. Vol. 4, No. 6 ; 5, Nos. 8, 12.

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Handbuch der Bodenkunde. Vols. 1-10.

Horticultural Educ. Assoc. Occasional Publ. No. 4.

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